2.0 Environmental Setting

2.1 Geology

The Site is located along Colorado's Front Range on the western margin of the Colorado Piedmont section of the Great Plains Physiographic Province (Spencer 1961), which also coincides with the western limit of the Denver Basin. The COU is primarily located on an alluvium-covered pediment; the general topography of this stream-bisected alluvial fan is evident on Attachment 1 to RFLMA. The surface of this alluvial deposit slopes approximately 1 to 2 degrees to the east.

The geologic history of the Colorado Rocky Mountain region, of which the Site is a part, is summarized in Haun and Kent (1965). Comprehensive geologic studies were performed as part of the Site characterization (e.g., EG&G 1991, 1995a, 1995b). Through these and other resources, including lithologic cores, geophysical logs, field geologic mapping, aerial photographs, and mine development (particularly along the western margin of the Site), a large quantity of lithologic and stratigraphic information was collected about the Site.

Surficial deposits at the Site predominantly include unconsolidated clastics of the Quaternary-age Rocky Flats Alluvium, hillslope colluvium, valley fill alluvium, and artificial fill. These deposits are often collectively and informally referred to as "alluvium"; they unconformably overlie the Cretaceous-age Arapahoe and Laramie Formations. Where present at Rocky Flats, the Arapahoe Formation often contains a basal sandstone unit that is important to groundwater transport; elsewhere, the dense claystones of the Laramie Formation (which also includes isolated lenses of siltstone and fine-grained sandstone) underlie surficial deposits. Underlying the Laramie Formation are the Fox Hills Sandstone and Pierre Shale. These units are steeply east-dipping and are not exposed at the Site except in the quarries along its western edge.

Structure at the Site is controlled by the Rocky Mountain uplift on the west and the Denver Basin on the east. The north-south trending Denver Basin is an asymmetrical feature containing Paleozoic, Mesozoic, and Cenozoic strata that dip steeply eastward along this western margin. In the area of the Site, the Denver Basin-related strata include Pennsylvanian to Cretaceous formations that are exposed in mines and stream valleys west of the Site.

Several faults have been identified in the area of the Site using seismic and stratigraphic techniques, and some are inferred (EG&G 1995a). These faults appear to be inactive and limited to bedrock formations rather than extending into the overlying surficial deposits. At the Site, the inferred faults appear to have limited hydrologic significance (RMRS 1996).

2.2 Hydrology

Streams and seeps at the Site are mostly ephemeral, with stream reaches gaining or losing flow depending on the season and precipitation amounts. Surface water flow across the Site is primarily from west to east, with three major drainages traversing the Site. Fourteen retention ponds (plus several small stock ponds) collect surface water runoff, although only 12 ponds are within the COU and maintained by DOE-LM. During October 2008 to March 2009 dams for six ponds are being removed to install flow-through stoplog structures. The reconfiguration is

discussed in more detail below. The Site drainages and retention ponds, including their respective pertinence to this report, are also described below and shown on Figure 1–2.

The major stream drainages leading off Site, from north to south, are Rock Creek, Walnut Creek, and Woman Creek. North Walnut Creek flows through the A-Series Ponds and South Walnut Creek flows through the B-Series Ponds; both are tributaries to Walnut Creek.

2.2.1 Walnut Creek

Walnut Creek receives surface water flow from the central third of the Site, including the majority of the COU. It consists of several tributaries: McKay Ditch, No Name Gulch, North Walnut Creek, and South Walnut Creek. These tributaries join Walnut Creek upstream of the Site's eastern boundary (Indiana Street). East of Indiana Street, Walnut Creek flows through a diversion structure normally configured to divert flow to the Broomfield Diversion Ditch around Great Western Reservoir and into Big Dry Creek. The Walnut Creek tributaries, from north to south, are described below.

McKay Ditch

McKay Ditch was formerly a tributary to Walnut Creek within the Site boundaries but was diverted in July 1999 into a new pipeline to keep McKay Ditch water from commingling with Site water in Walnut Creek. Although no longer a contributor to Walnut Creek, the McKay Ditch drainage is described here to clarify water routing at the Site. The new configuration allows the City of Broomfield to transport water from the South Boulder Diversion Canal, across the northern portion of the POU and directly into Great Western Reservoir, without entering Walnut Creek. This configuration prevents commingling of McKay Ditch water with discharged water from the Site retention ponds. McKay Ditch, the McKay Bypass Canal, and the McKay Bypass Pipeline are outside the COU; these features are not maintained by DOE-LM.

No Name Gulch

This drainage is located downstream of the Landfill Pond, referred to historically as the East Landfill Pond. A surface water diversion ditch is constructed around the perimeter of the PLF to divert surface water runoff around the landfill to No Name Gulch. Effluent from the Present Landfill Treatment System (PLFTS) and runoff from the area surrounding the pond are the sole surface water sources to the Landfill Pond. The pond is normally operated in a flow-through configuration, although the pool level periodically drops below the outlet works.

North Walnut Creek

Runoff from the northern portion of the COU flows into this drainage, which has two retention ponds (Ponds A-3 and A-4). Two former ponds, A-1 and A-2, were breached in 2008 and now function as flow-through structures. The combined capacity of the remaining A-Series Ponds is approximately 168,433 cubic meters (m^3) (44.5 million gallons [MG] or 136.6 acre-feet). In the normal operational configuration, streamflow passes through Ponds A-1 and A-2 to maintain wetland habitat; water levels in these ponds are controlled by evaporation or flow-through stoplog structures to Pond A-3 for retention. North Walnut Creek flow can also be diverted through the North Walnut Creek Bypass Pipeline around Ponds A-1 and A-2 to Pond A-3 for retention. Pond A-3 is discharged in batches to the A-Series "terminal pond," Pond A-4. When

routine discharge of retained water in Pond A-4 is warranted, Pond A-4 is isolated, sampled, and water is released if surface water quality criteria are met (in accordance with Figure 13 in Attachment 2 to RFLMA; see Section 6.1.11 for a discussion on surface water quality criteria). If criteria are not met, appropriate pond management actions will be determined after consultation in accordance with RFLMA. Criteria for emergency discharge, regardless of pre-discharge pond sampling results, are detailed in the *Emergency Response Plan for the Rocky Flats Site Dams* (ERP) (Attachment B2).

South Walnut Creek

Runoff from the central portion of the COU flows into this drainage, which has one retention pond (B-5). Four former ponds, B-1, B-2, B-3, and B-4, were breached in 2008−2009 and now all function as flow-through structures. The capacity of Pond B-5 is approximately 87,434 m^3 (23.1 MG or 71 acre-feet). Streamflow passes through Ponds B-1, B-2, B-3, and B-4 to maintain wetland habitat; water levels in these ponds are controlled by evaporation or flow-through stoplog structures to Pond B-5 for retention. South Walnut Creek flow can also be diverted through the South Walnut Creek Bypass Pipeline around Ponds B-1, B-2, and B-3 and into Pond B-4, which flows directly into "terminal pond" Pond B-5. If routine discharge of retained water in Pond B-5 is warranted, Pond B-5 is sampled and water is released if surface water quality criteria are met (in accordance with Figure 13 in Attachment 2 to RFLMA; see Section 6.1.11). If criteria are not met, appropriate pond management actions will be determined after consultation in accordance with RFLMA. Criteria for emergency discharge, regardless of pre-discharge pond sampling results, are detailed in the ERP (Attachment B2).

2.2.2 Woman Creek

In the southern portion of the COU is Woman Creek, which flows through Pond C-1 and off Site onto Refuge lands toward Indiana Street. The Woman Creek drainage basin extends eastward from the base of the foothills, near Coal Creek Canyon, to Standley Lake. In the current configuration, Woman Creek flows into the Woman Creek Reservoir located east of Indiana Street and upstream of Standley Lake, where the water is held until it is pump-transferred to Big Dry Creek downstream of the Great Western Reservoir by the Woman Creek Reservoir Authority.

South Interceptor Ditch

The South Interceptor Ditch (SID) drainage is located in the southern portion of the COU and is a tributary to Woman Creek. Surface water runoff from the southern portion of the COU is captured by the SID, which flows from west to east into Pond C-2. The capacity of Pond C-2 is approximately 85,920 m^3 (22.7 MG or 69.6 acre-feet). If routine discharge of retained water in Pond C-2 is warranted and surface water quality criteria are met (in accordance with Figure 13 in Attachment 2 to RFLMA; see Section 6.1.11), Pond C-2 is sampled and water is released to Woman Creek. If criteria are not met, appropriate pond management actions will be determined after consultation in accordance with RFLMA. Criteria for emergency discharge, regardless of pre-discharge pond sampling results, are detailed in the ERP (Attachment B2).

2.2.3 Other Drainages

The third major drainage, in addition to Walnut and Woman Creeks, is Rock Creek. The Rock Creek drainage covers the northwestern portion of the former RFP/Rocky Flats Environmental Technology Site (RFETS). East-sloping alluvial plains to the west, several small stock ponds within the creek bed, and multiple steep gullies and stream channels to the east characterize the drainage channel. This entire basin is located in USFWS Refuge lands outside the COU.

Smart Ditch/South Woman Creek, located south of Woman Creek, is also completely outside the COU. The D-Series Ponds (D-1 and D-2) are located on the Smart Ditch. This drainage and these ponds are not maintained by DOE-LM.

2.3 Hydrogeology

Groundwater flow at the Site occurs in the upper hydrostratigraphic unit (UHSU), which comprises the surficial deposits and subcropping weathered bedrock of the Arapahoe and/or Laramie Formations. The UHSU is roughly analogous to the "upper aquifer" at the Site, although in many areas the amount of groundwater available is insufficient to meet the definition of an aquifer in 40 *Code of Federal Regulations* (CFR) 260.10 (K-H 2005).

The Site is in a regional groundwater recharge area (EG&G 1991). Direct precipitation and baseflow along the upgradient portion of the Site's drainage basin (which extends west to Coal Creek) are the source of UHSU recharge. Infiltrating precipitation is reduced significantly by evapotranspiration (ET) (K-H 2002a); this loss increases near streams due to the shallower groundwater and more abundant vegetation.

The bedrock surface closely resembles the surface topography and represents the main control on groundwater migration. Groundwater flows laterally through the unconsolidated surficial materials because its vertical transport is limited by the relatively low-permeability bedrock claystones. Groundwater resources in the regional Laramie/Fox Hills Aquifer are separated from the UHSU by several hundred feet of these upper Laramie Formation claystones, which act as an aquitard and restrict the occurrence of contaminated groundwater to shallower intervals.

The general direction of groundwater flow Site wide is from west to east. Locally, this is modified by the presence of drainages. As groundwater within the UHSU of a pediment flows toward the east and nears a drainage, the topographic depression represented by that drainage diverts the groundwater toward it, and the groundwater discharges to surface water either as seepage or baseflow. This results in considerable hydraulic connection between surface water and groundwater at the Site. Segments of streams have been shown to either gain or lose water as groundwater is discharged to streams, or stream water is discharged to groundwater from the stream channel. Groundwater discharges to surface water prior to leaving the Site. Therefore, gaining reaches of streams in the COU are more likely to receive groundwater impacted by past RFP/RFETS activities, and have traditionally been the focus of most groundwater monitoring.

In addition to natural hydrologic processes, groundwater can also be transported to surface water directly through former utility corridors, building sumps, foundation drains, and sanitary sewers. While these systems have been removed or disrupted as part of RFP/RFETS closure, the trenches in which they were installed may still represent preferential pathways for groundwater. Overall, water quality data pertaining to these corridors have indicated that their importance as

preferential pathways for contaminated groundwater migrating to surface water is relatively minor.

Depth to groundwater is greatest in the western portion of the Site, where the Rocky Flats Alluvium can exceed 100 feet in thickness. As the Rocky Flats Alluvium thins toward the east, the depth to groundwater and the saturated thickness decrease. In some portions of the Site, groundwater is absent from the UHSU or is present only within the weathered bedrock, decreasing groundwater flow velocities due to the lower hydraulic conductivity of the weathered claystones. However, where the basal Arapahoe Formation sandstone (informally referred to in geologic and hydrologic studies at Rocky Flats as the Arapahoe Sandstone No. 1) forms part of the UHSU, flow velocities tend to increase in comparison to the Rocky Flats Alluvium or claystone due to the higher conductivity of this material. This sandstone unit therefore comprises a preferential flow path, such as in the East Trenches area and elsewhere. Maps of this sandstone are included in earlier RFP/RFETS reports. For example, refer to the isopach and isolith maps in the *Geologic Characterization Report for the Rocky Flats Environmental Technology Site* (EG&G 1995a). (Note that this depiction was not updated following the collection of additional lithologic information.)

Numerous potentiometric surface maps have been generated for the RFP/RFETS and for smaller areas (DOE 2008a, 2007c, 2006c; K-H 1997, 1998a, 1999, 2000a, 2001, 2002b, 2004c, 2004d, 2005; EG&G 1995a, 1995b). While not required by the RFLMA, these maps are useful indicators of changing conditions, particularly with respect to groundwater gradients and flowpaths. Potentiometric surface maps and groundwater flow velocities for the second and fourth calendar quarters of each year are therefore included in annual reports.

2.4 Ecology

Vegetation communities at Rocky Flats provide specific habitats for associated wildlife, rare plants, and unusual plant associations. These communities include the xeric mixed grassland, mesic mixed grassland, high-quality wetlands, tall upland shrubland, Great Plains riparian woodland complex, and reclaimed grassland communities. The aquatic ecosystem at the Site consists primarily of ephemeral and intermittent streams, old stock ponds, and several water management impoundments. The Preble's meadow jumping mouse (hereafter referred to as the Preble's mouse) (*Zapus hudsonius preblei*) is of particular concern because it is a federally listed threatened species under the Endangered Species Act (ESA), which provides special protection for the species.

The descriptions that follow describe the ecology in both the COU and POU areas and are referred to as occurring at "the Site." Although the RFSOG is written to address the COU activities, the ecological setting of the COU is part of the larger, regional, and historical Rocky Flats Site and is therefore described as such.

2.4.1 Xeric Mixed Grassland

There are two types of xeric mixed grassland units at the Site: the xeric tallgrass prairie and the xeric needle-and-thread grass prairie. Identification of the xeric tallgrass vegetation community is based on the presence of big bluestem (*Andropogon gerardii*), little bluestem (*Andropogon scoparius*), prairie dropseed (*Sporobolus heterolepis*), Indian-grass (*Sorghastrum nuntans*), and switchgrass (*Panicum virgatum*). These five species are considered to be tallgrass prairie relicts.

Of these species, only big bluestem and little bluestem are abundant at the Site. When the foliar cover of these five species is approximately 10 percent or more of a xeric mixed grassland community, the community is classified as xeric tallgrass prairie. The soil in a xeric tallgrass prairie is visibly cobbly on the surface, and is considered to be a sandy clay loam. This vegetation community covers the high, rocky pediment on the western third of the Site. The xeric tallgrass prairie has been classified as a rare plant community type for Colorado and North America by the Colorado Natural Heritage Program.

The other type of xeric mixed grassland, the xeric needle-and-thread grass prairie, is also considered rare at the Site. Xeric needle-and-thread grass prairie is differentiated from xeric tallgrass prairie by a greater cover of needle-and-thread grass (*Stipa comata*) and New Mexico feather grass (*Stipa neomexicana*) than big bluestem and little bluestem or other tallgrass species. The soils beneath the xeric needle-and-thread grass prairie are not as cobbly as those in the xeric tallgrass prairie, and have a higher visible component of caliche at the soil surface. This vegetation community occupies the tops of many of the easternmost ridges of the Site.

2.4.2 Mesic Mixed Grassland

Mesic mixed grassland is characterized by western wheatgrass (*Agropyron smithii*) and blue grama grass (*Bouteloua gracilis*). Other common species include green needlegrass (*Stipa viridula*), Canada bluegrass (*Poa compressa*), and Kentucky bluegrass (*Poa pratensis*). The mesic grassland has a more solid turf appearance in contrast to the bunchgrass appearance of the xeric mixed grasslands. Surficial soils are clay loams that do not have the cobbly appearance typical of xeric mixed grassland soils. Most hillsides at the Site are considered mesic mixed grassland habitat.

The quality of these grasslands varies considerably across the Site depending on the annual precipitation received. Non-native species such as diffuse knapweed (*Centaurea diffusa*), Japanese brome (*Bromus japonicus*), dalmatian toadflax (*Linaria dalmatica*), alyssum (*Alyssum minus*), musk thistle (*Carduus nutans*), common mullein (*Verbascum thapsus*), Scotch thistle (*Onopordium acanthium*), and others are often very abundant in wet years. For classification purposes, a grassland is designated as mesic mixed if western wheatgrass and blue grama grass form an understory beneath non-native species, regardless of dominance by non-native species.

Mesic mixed grasslands comprise one of the largest contiguous vegetation communities at the Site. In addition to its essential role as a foraging habitat, the size and isolation of the mesic mixed grassland often makes it very important to certain wildlife species. A wide variety of grassland birds breed and forage in this habitat. Small mammals are abundant and diverse, and provide a suitable prey base for a variety of avian and mammalian predators. Many of the species supported by this vegetation community are rare or of special concern.

2.4.3 High-Quality Wetlands

Several high-quality wetlands are present at the Site with the largest contiguous areas and the most complex plant associations found at the Rock Creek and Antelope Springs/Apple Orchard Springs Complexes.

The Rock Creek wetlands are a large, seep-fed wetland complex extending approximately 1 mile from the foot of the easternmost seep-fed wetlands to the westernmost short marsh areas. The

Antelope Springs/Apple Orchard Wetland Complex encompasses the predominantly wet meadow, short marsh, and tall marsh habitat mosaic of the upper Woman Creek Drainage Basin. These are also seep-fed wetlands that depend on groundwater discharge for their continued existence.

Predominant vegetation in these wetlands includes cattails (*Typha sp.*) and bulrush (*Scirpus sp.*) in tall marsh community; Nebraska sedge (*Carex nebraskensis*) and Baltic rush (*Juncus balticus*) in short marsh habitat; and prairie cordgrass (*Spartina pectinata*), redtop (*Agrostis stolonifera*), showy milkweed (*Asclepias speciosa*), and Missouri iris (*Iris missouriensis*) in wet meadow habitat.

These wetlands support a variety of terrestrial and aquatic organisms. Portions of these wetlands have been designated as prime Ute Ladies'-tresses (*Spiranthes diluvialis*) habitat (a federally listed threatened plant that may occur at the Site). Searches for this species have never documented its existence at the Site, however. Other portions support sensitive amphibian species and waterfowl. Many predatory mammals and bird species depend on these areas as hunting and foraging grounds due to their high prey species productivity.

2.4.4 Tall Upland Shrubland

The tall upland (seep) shrubland comprises stands of hawthorn (*Crataegus erythropoda*), chokecherry (*Prunus virginiana*), and occasionally wild plum (*Prunus americana*). Tall upland shrubland is found primarily on north-facing slopes above seeps, wetlands, and streams in the Rock Creek drainage north of the Site, but small units also occur across the Site. This vegetation community may be unique, because no similar units have been identified outside the general Site vicinity. It is important habitat for the resident mule deer (*Odocoileus hemionus*) population. Mule deer are highly reliant on tall upland shrubland for fawning cover, winter thermal cover and browse, and summer shade and isolation cover. A number of rare bird species (e.g., bluegray gnatcatchers [*Polioptila caerulea*] and chestnut-sided warblers [*Dendroica pensylvanica*]) occupy this community as well. Some units of tall upland shrubland also provide habitat for the threatened Preble's mouse.

2.4.5 Great Plains Riparian Woodland Complex

Riparian areas are well known for the diversity of plant and animal species they support. The riparian woodland complex at Rocky Flats is a combination of two vegetation community classifications: riparian woodland and riparian shrubland, which form a complex mosaic habitat along the drainage bottoms at the Site. Due to its contiguous mixture of both trees and shrubs, the riparian areas are described as a complex. The woodland component of the complex is characterized by stands of plains cottonwood (*Populus deltoides*), peach leaf willow (*Salix amygdaloides*), Siberian elm (*Ulmus pumila*), and silver poplar (*Populus albus*). The shrubland component of the complex includes chokecherry, snowberry (*Symphoricarpos occidentalis*), coyote willow (*Salix exigua*), leadplant (*Amorpha fruticosa*), and other shrubs.

The riparian woodland complex is an important habitat for a different songbird association than the grasslands and shares some species with the tall upland shrubland. Several of the bird species using the riparian woodland complex as foraging and nesting cover are rare species (e.g., blue grosbeak [*Guiraca caerulea*]). Like the tall upland shrubland community, this vegetation community is also seasonally important to the resident mule deer herd as shelter, forage source,

and fawning grounds. Large cottonwood trees embedded within this unit provide nesting habitat for several raptor species, including the great horned owl (*Bubo virginianus*), red-tailed hawk (*Buteo jamaicensis*), Swainson's hawk (*Buteo swainsoni*) (a Colorado "at-risk" species), and American kestrel (*Falco sparverius*). The riparian woodland complex supports the greatest number of Preble's mice at the Site and is considered typical habitat for this species.

2.4.6 Reclaimed Grasslands

The reclaimed grassland communities are areas that were disturbed and planted with non-native graminoid species. These areas are dominated by species such as smooth brome (*Bromus inermis*), intermediate wheatgrass (*Agropyron intermedium*), and crested wheatgrass (*Agropyron cristatum*). They are typically low in diversity for both plants and animals.

2.4.7 Aquatic Community

The aquatic ecosystem at Rocky Flats consists of a network of primarily ephemeral and intermittent streams and several scattered old stock ponds. In the Walnut Creek and Woman Creek drainages, there are several ponds (see Section 2.2) that retain large bodies of water. Several mitigation wetland areas were created for mitigation of wetland disturbances related to Site closure activities. These are located primarily in the COU in the North and South Walnut Creek drainages. Numerous seep springs feed streams at the Site and provide limited wetland habitat. Other than the outflow of the seeps and the water in the existing ponds and larger pools, very little permanent surface water exists at the Site. Macroinvertebrate populations typical of ephemeral streams and limited small populations of fish are found in the various waters at the Site (Aquatic Associates 1998, K-H 1998b, DOE 2003).

2.4.8 Preble's Mouse Habitat and Populations

The Preble's mouse is a species of particular concern at the Site because it is listed as threatened by USFWS. This listing provides special protection for the species under the ESA, and actions must be evaluated for potential impact to the mouse.

Preble's mice have been recorded in the major drainages of the Site: Walnut Creek and Woman Creek drainages. Native plant communities in these areas provide a suitable habitat for this small mammal. Preble's mouse populations are found in association with the riparian zone and seep wetlands and apparently prefer multistrata vegetation with abundant herbaceous cover. The vegetation communities that provide Preble's mouse habitat include the Great Plains riparian woodland complex, tall upland shrubland, the wetlands adjacent to these communities, and some of the upland grasslands surrounding these areas. All activities occurring in Preble's mouse habitat require approval from USFWS prior to initiation. Figure 2–1 shows the locations of Preble's mouse protection areas (habitat) at Rocky Flats.

2.4.9 Revegetation Areas

During previous cleanup and closure activities, large areas of the former IA were disturbed and reconfigured. These areas were revegetated using native plant species common to the native grasslands at the Site. As of the end of the 2007 growing season, most of the revegetated areas were in the early successional stages of returning to a natural, native ecosystem. Proactive management of these areas through weed control and reseeding efforts will be required for many years before these areas resemble the native grasslands at the Site.

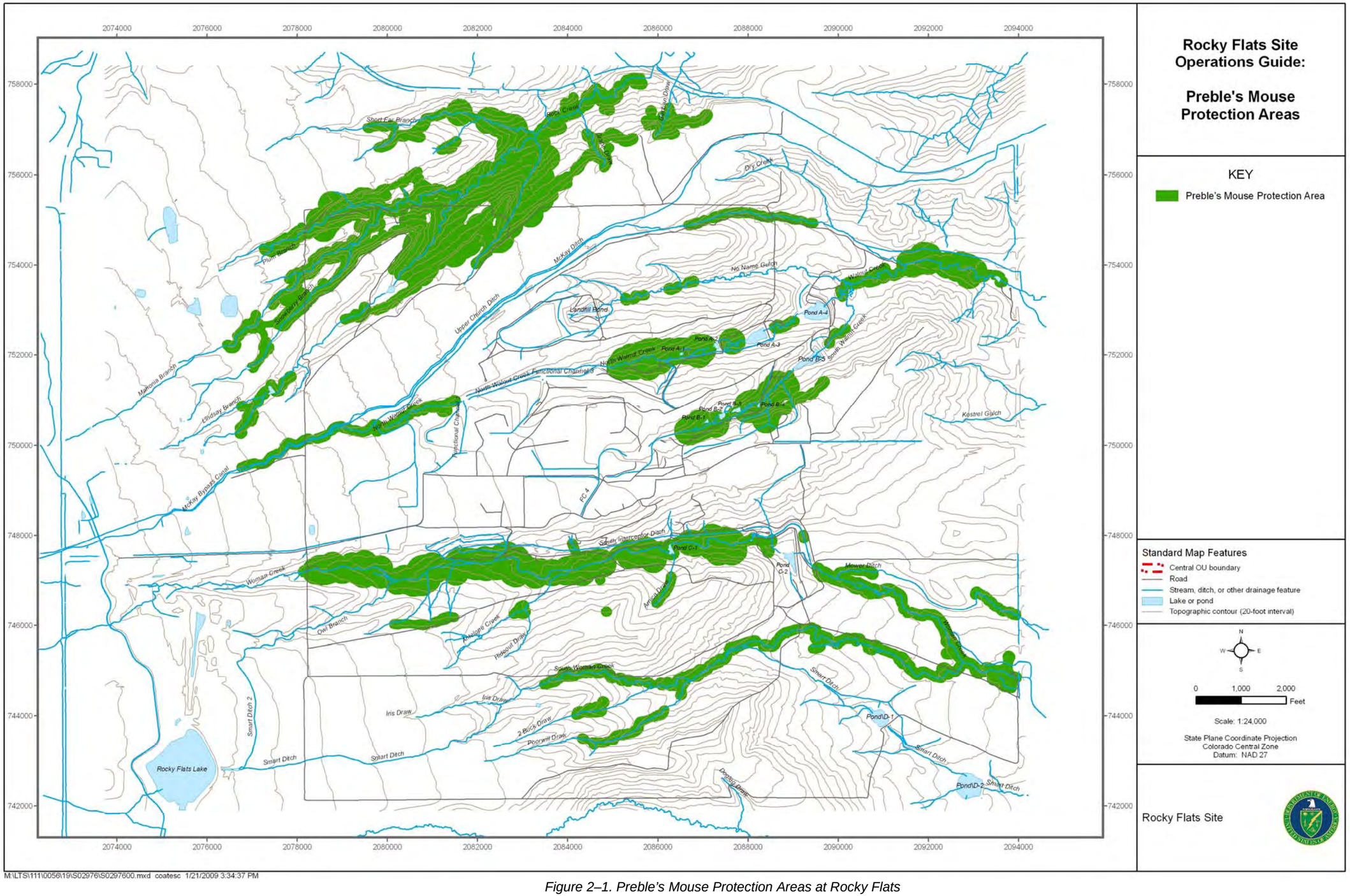

Figure 2–1. Preble's Mouse Protection Areas at Rocky Flats

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